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THE GLASS INDUSTRY

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GLASS DIVISION SUMMER MEETING

New type of program offers fewer papers, of more fundamental character. Penn State holds open house and glass men find research projects, laboratories, museums filled with interest. Attendance among the largest.

Once again the Glass Division of the American Ceramic Society has presented convincing evidence that it continues a strong, unified and progressive group. At its summer meeting held last month at Pennsylvania State College, more than a hundred members were in attendance; in striking contrast to the initial meeting of 1929, held at the cottage of Francis Flint on Chesapeake Bay, and one that calls attention to the great growth that has taken place in this annual conference.

Distinguished guests present included Dr. Robert B. Sosman, president of the American Ceramic Society, and Dr. Ross Purdy, dynamic secretary. Dr. Littleton, back for the first meeting since his regrettable accident, was given an informal welcome, notable for its genuine warmth and sincerity. Dr. R. W. Schultze, guest of honor, brought greetings from our colleagues in Germany.

Chairman Finn called the opening session to order at 11 o'clock on Friday morning, and Dr. Taylor of the Department of Ceramics, Pennsylvania State College, officially welcomed the Division. Following formal introductions and exchange of courtesies, papers were read, summaries of which appear on succeeding pages.

The afternoon schedule called for a tour of the Mineral Industries Building, and this proved something of a revelation to many. Among the projects in the School of Mineral Industries of particular interest to glassmen were Diffusion of Gases Through Glass; Elastico-Viscous Properties of Glass; Reactions in Solid State; Color Reactions in Glass; and Studies on Limestones. The men in charge of these various researches were on hand to explain them. A visit was made to the Museum, which contains among its mineral collections a most unusual collection of silicates. Another feature is a collection of paintings depicting activities of the various mineral industries, which is said to be one of the finest collections of industrial paintings in the country.

Golfers had a double bill, first at the Country Club and later on the beautifully kept fairways of the University course. The tournament was won by Vic Kelsey (94-24-70), who nosed out Dr. Littleton by a single stroke. Williams and Treishel were close on their heels.

During the evening, the conference was entertained at the Center Hills Country Club by the Pennsylvania Glass Sand Company. Following a banquet and speech making, an excellent floor show was put on by Penn State students.

These are merely the high lights of many events and occurrences that combined to make this year's meeting another notable success. Turning to the papers and addresses, we find quite a definite change from previous meetings—fewer papers, fundamental in character and designed to bring forth general but narrowly directed discussion.

We might summarize by saying that Dr. Lundell demonstrated how far we can go in finding the exact composition of glasses; that Dr. Taylor brought together the evidence as to constitution of glass so far as it is revealed by studies of viscosity; that Dr. Warren again brought up to date the approach to constitutional knowledge gained by a study of the x-ray patterns of glasses; and that the tremendous difficulties in the way of arriving at satisfactory figures for the mechanical strength of glass were completely set forth by Dr. Navias in his review of the exhaustive work done by the sub-committee of the A.S.T.M. on this project.

From the point of view of the man in the plant, these papers might be criticized as to their lack of practical, every-day application to the problems in hand. However, if we can take lessons from other fields of manufacturing, we may be assured that the real progress of our own industry will best be served by acquiring more and more fundamental and scientific information about our material. One important generality is that the limitations of our knowledge must be more clearly recognized, whether these limitations apply to composition, internal structure, or specific physical properties.

There are all too many analyses recorded in the literature, carried out neatly to two decimal places, when the skill of the analyst has not been sufficient to permit arriving at total summation within five points in the first decimal place. We like to dream about compounds in our glasses; but real evidence for compounds, meeting prescribed definition for compounds, still eludes the investigator. Perhaps it is entirely fair to remark, just here, that when the analysis of x-ray patterns discloses that no crystallites can be present, and it can be further demonstrated logically that no "molecules" can be present, we are left a little confused about the "molecules" which the physicist has in mind in his explanations of

the phenomena of heat. Perhaps he means "atoms," all the time. Perhaps, too, the association and dissociation suggested as explanations for the changes in viscosity of glasses, depending upon their heat treatment, require some degree of chemical action not revealed by the x-ray as any structural unit. Certainly there is nothing final about all the evidence thus far gathered. The liquid state remains in our minds in about as bad shape as the state of West Virginia.

The glass technologist is not yet ready to tell the engineer how strong his glass is. At any rate, we are not giving out a set of numbers based on the apparent strength of certain things made of glass, and announcing that we have numbers representing the actual tenacity of the material. The practical men may learn, from the apparent confusion and futility of strength measurements, that he must give increased attention to the preparation and protection of the surfaces of glassware, to the design of contours and cross sections and to the heat treatment of the product. Disappointing as these disclosures are, they have lost us nothing except some apparent information which was never actually real. There is a satisfying sincerity about our present approach to this baffling problem of mechanical strength, even though its challenge to the imagination and the experimental skill of the physicist has not been met.

At this meeting we were again reminded of the unified and coordinated attack upon the fundamental problems of glass technology, organized through the International Congress, under the leadership of the International Commission on Glass. The welcome presence of Dr. Schultze was an additional reminder of the concerted international effort to point our researches at very definite goals.

New Developments and Ideas in Analytical Chemistry of Interest to the Glass Industry, by G. E. F. Lundell.

Demands on analysts of glass promise to become more varied and exacting as compositions of glass become more complex, particularly if glass enters the structural materials field and becomes subject to "chemical requirements" such as govern acceptance of metals and alloys.

In this field, analysts encounter some 25 elements regularly, and some 20 others quite often, a total of more than half of the elements. In addition to the variety of elements encountered, the analyst must also work to rather close specifications, such as a maximum of 0.002 per cent of bismuth in copper, or a minimum of 98.75 per cent of tin in pig tin.

To meet these demands, the analyst is still forced to rely on methods that are far from specific or even selective. Precipitation by ammonium hydroxide and the reporting of the weight of the ignited precipitate as "R_2O_3" is still used, although approximately one-third of the elements are completely precipitated by this reagent, and about one-third of the remaining elements may be more or less completely carried down by the precipitate. Similarly, hydrogen sulphide precipitates some 23 elements, and the precipitate may be contaminated by 8 others, again a total of nearly one-third of all the elements. Like considerations hold in other methods of determination, volumetric, electrolytic and colorimetric.

One obvious relief from this situation is a search for and the development of more selective or specific methods of determination, methods that will be affected by no more than two or three elements, or better still, by no element other than the one in question. We have no perfect examples of the latter, but we have a few of the former, such as the dimethlyglyoxime method for nickel, or the α —benzoinoxime method for molybdenum.

What has been said has had to do with determinations of major constituents of everyday materials. Another problem that is fast coming to the fore is the determination of constituents that occur in very small amount and which may be of importance in their effect on physical properties or in the selection of raw materials. The number of elements that may be found in everyday materials is surprising. More than 30 of the elements have been found in ordinary phosphate rocks, at least 20 in clays, and some 25 in metallic aluminum.

One of the chief drawbacks to the application of macro methods of analysis to the determination of minor constituents of materials is the size of sample that must be taken, and the care that must be taken in the choice of reagents and in the determination of the corrections for the "blank." As for the first, 100 grams of sample is none too much for an accurate gravimetric determination of a constituent in the 0.001 per cent range. An exaggerated, but none the less instructive, illustration of the importance of careful attention to blank corrections has been cited in connection with the determination, through the uranium-lead ratio, of the age of a specimen of samarskite mineral containing 7 per cent of uranium. In this particular case, failure to correct for a 0.001 per cent content of lead in the reagents used in the determination would cause an error of 78 millions of years in the reported age of the mineral.

Up to the present time, the analyst of ceramic materials has not been subjected to the constant cross-checking by other analysts, that is the lot of analysts of metals and alloys. When he is, methods of determinations and accuracy of results must be examined much more closely than at present. The difficulty in choosing the best method, and in establishing the most probable value for a constituent can be illustrated by the certification of the iron content in the National Bureau of Standards Sibley Iron Ore, No. 27b. In the standardization of this ore, seven different methods, two gravimetric and five volumetric, were critically studied before the most probable value for the iron content was certified. The problem of establishing the most probable value is difficult enough when all determinations are made in one laboratory; if the determinations are made in different laboratories the value cannot be chosen unless details of the methods of determination are at hand, and the judge is capable of weighing the evidence.

Finally, a few words might be added concerning future trends in the chemical analysis of glass. I believe that the old classical method of analysis for silica, "R_2O_3," calcium oxide and magnesium oxide (fusion, separation of silica and precipitation in turn with ammonium hydroxide, ammonium oxalate and ammonium phosphate) will be replaced by unit methods which are applied to separate samples, as is done in the steel industry. In this work continued search will be made for more specific methods. For the determination of the minor constituents, I believe that we shall see an increasing use of such valuable tools as chemical spectroscopy, and microanalytical methods. To these we may also add polarographic methods, when more thoroughly investigated.

A. N. Finn

Viscosity and Resistivity and Their Bearing on the Nature of Glass, by Dr. N. W. Taylor, Dept. of Ceramics, Pennsylvania State College.

The "ideal internal energy curve" recently constructed by Preston and Seddon is based mainly on two properties, viscosity and electrical conductivity. Since both viscosity (η) and electrical resistivity (r) are rate phenomena, the term "activation energy" may better be used to denote the energy term derived from a plot of log η or log r, thus,

$$E_\eta = \frac{2.3\ R \log \eta_1 / \log \eta_2}{1/T_1 - 1/T_2}$$

$$E_r = \frac{2.3\ R \log r_1 / \log r_2}{1/T_1 - 1/T_2}$$

where T is the absolute temperature and R is the gas constant.

Preston and Seddon have correctly identified the terms E_η and E_r as measuring the heights of the potential barrier around the equilibrium position of the atoms in the glass, but difficulties arise when they attempt to extrapolate the curve to zero, because they assume that their "internal energy" will drop to zero. The author, therefore, questions some of the experimental data on viscosity and electrical conductivity at lower temperatures.

Stabilized and Non-Stabilized Glasses — Preston and Seddon's "internal energy" curve shows a maximum at about the softening point, but in 1933 Lillie showed that viscosity changes steadily with time of heat treatment until a finite equilibrium viscosity is reached. He also showed that the softening point had no significance. The author believes that the length of time required to reach equilibrium at the lower temperatures was in excess of the time allotted for the measurement. As the temperature is lowered the times become days, months or years.

The hump in the curve may be explained by analogy with NH_3, and the author shows that in the formation of NH_3 from N_2 and H_2 the maximum yield is secured at an optimum temperature. This is the temperature at the point where the curve of % NH_3 in the equilibrium mixture and the curve rate of NH_3 formation cross. Littleton has stated that "viscosity changes with time just as do the other physical properties of glass. Apparent discontinuities are due to insufficient time for stabilization." Littleton and Wetmore have also presented data on the electrical resistance of certain glasses in the chilled, annealed and stabilized states. In the latter case there was no break in the log R vs. log T curve at a "transformation point." These facts indicate that the activation energy curve is a continuous line and has no maximum, as shown by Preston and Seddon.

Molecular Forces in Liquids—Using values of the quantity B, calculated from the Guzman equation

$$\eta = A\, e^{-B/RT}$$

it is shown that these values decrease with increasing size of ion in typical ionic fluid without directional forces, and are very much higher for an ionic liquid with directional forces (B_2O_3). Non-polar molecular liquids, dipolar molecular liquids and molecular liquids with hydroxyl bonds have comparatively small values for B.

In ionic liquids the whole structure is a continuous lattice and when viscous shear occurs the process is not so localized as in the case of molecular liquids. The activation energy should be correspondingly larger. Bernal shows that the molecular structure of a simple liquid is described by three variables, the mean distance of closest approach of molecules, the number of close neighbors of any molecule, and the irregularity of distribution.

The quantity B, therefore, represents the energy which must be supplied to bring about a configurational change under the shearing stress. For ionic liquids B will be large when the valence is large, when there are strong directional forces, and when the coordination number is small. Evidence exists to show that the substitution of an ion by one of higher valence leads to an increase in the temperature coefficient of viscosity.

The Oxygen-Silicon Ratio—Preston and Seddon have also made a special study of soda-silica glasses, using the viscosity data of Heidtkamp and Endell, the curve being a plot of E_η vs. % Na_2O. The curve shows inflections at points in the curve corresponding to the compounds $Na_2O.2SiO_2$ and $Na_2O.SiO_2$, from which they infer that these compounds must be present in the glass. W. L. Bragg has shown, however, that the structure of silicate crystals is very largely determined by the ratio O/Si. When O/Si = 4, there are separate SiO_2 groups, or tetrahedra, not connected except through metallic cations; when O/Si = 3, the tetrahedra link to form chains as in the pyroxenes; when O/Si = 2.5, a "sheet" structure is formed which, in the simplest and most common form, is a hexagonal network; finally when O/Si = 2 (SiO_2), a three-dimensional network is formed.

It is the author's opinion that this concept can be carried over to glass and that the inflections in Preston and Seddon's curve may simply mark the change from one type of structure to another.

Electrical Conduction in Glass and Its Activation Energy—Phipps and Leslie have shown that in sodium chloride crystals the positive ion, sodium, carries practically all the current in the lower temperature range, and that it filters through the negative ion lattice under the influence of the applied electrical field. At higher temperatures both ions move and carry current, and the activation energy is roughly doubled. Where the salt has a mixed valence, the ion of lower valence usually carries nearly all the current unless the temperature is very high. From figures given by Gelhoff and Thomas on the temperature at which the conductivity of some glasses reaches a certain value, it may be inferred that the energy term, derived from the temperature coefficient of the electrical conductivity, is the critical increment of energy which the conducting ions of a lattice must acquire in order to be free to move under the influence of the applied field. Electrical conduction appears to be a kind of filtration process, not involving a general break-down of the whole ionic lattice as does viscous shear.

The Internal Engery-Temperature Relation for Glass —At any temperature T the magnitude of the internal energy is given by the relation

$$E = \int_0^T C_v dT + E_o,$$

where E_o is the energy at absolute zero. In the case of glasses there is no great error in substituting C_p for C_v,

since values of C_v are not as readily available as of C_p, the specific heat at constant pressure. From values of C_p given by Kelly it is possible to evaluate the heat content Q above 273.1° K., where Q is defined by the relations

$$C_p = a + bT - cT^{-2}$$

and

$$Q = \left[aT + \frac{bT^2}{2} + cT^{-1} \right]_{T_1}^{T_2}$$

These values rise continuously with the temperature and there is no minimum or maximum at any intermediate temperature, in contrast to the shape of Preston and Seddon's curve. Similar behavior is shown by other specified glasses.

Influence of Temperature on the Structure of Glass—There is a more or less general agreement that a linear log η vs. 1/T or log r vs. 1/T relation indicates a constant or fixed molecular structure subject only to changes in amplitude of motion, but not undergoing significant changes in configuration, i.e., in coordination. Relations are, therefore, interpreted in terms of progressive dissociation of complex aggregates as the temperature rises. Naturally, the weakest bonds would dissociate first, while the strongest would persist to the highest temperatures. Due to the random or irregular nature of the network, all intermediate cases are possible, so that the curve is continuous.

Discussion—Noting that the values of B from the Guzman equation were about the same for both soda-lime and lead glasses (150 k. cal. in the viscosity range 10^{11}—10^{15} poises), Dr. Sosman expressed surprise that the data should show such a result. Dr. Taylor thought that possibly the two values might be taken from different points on the curve. E. P. McNamara stated that there really seemed to be very little difference in the activation energy for the two types of glass.

Responding to a request by Finn for a definition of softening temperature, McNamara suggested temperature at which equilibrium can be reached quickly.

The Mechanical Properties of Glass: Their Significance and Determination, by Louis Navias, General Electric Co.

Dr. Navias summarized the results of cooperative tests on the mechanical strength of glass, performed under the direction of a committee whose chairman is J. T. Littleton. The committee was organized in Jan., 1935, and the cooperating laboratories have been Bureau of Standards, Bailey & Sharp, Inc., Corning Glass Works, General Electric Co., Hartford-Empire Co., Owens-Illinois Glass Co. and F. W. Preston.

It was planned to test compressive strength, transverse breaking strength, thermal endurance and thermal shock. Most of the work so far has been done on compressive and transverse breaking strength. Navias reported test results prior to July, 1936, at a meeting of Technical Group II at the International Congress on Glass last summer, the figures being given in *Transact. Soc. Glass Tech.*, Vol. 20, 1936. The present report serves to acquaint Glass Division members with subsequent tests and proposed action.

The compressive strength tests were made in the General Electric Co. laboratories on test specimens in which the diameters were equal to their heights, which were ¼ in., ½ in., and ¾ in. A borosilicate and a soda-lime-silica glass were tested and the results showed rather wide variations, both for different sizes of sample and for different test conditions.

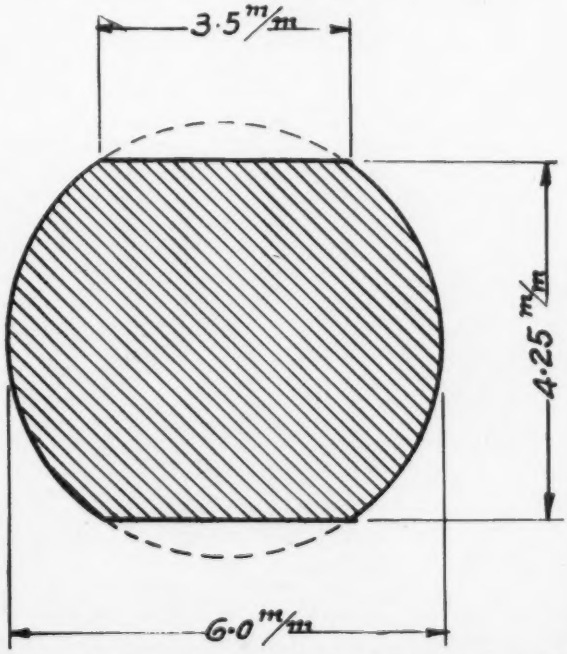
Tests for transverse breaking strength have yielded the largest amount of data, but so far the figures show so little uniformity as to make it impossible to draw any conclusions or to set up any standard test. These tests have, however, pointed out the necessity for standard samples, a standard method for prematurely aging the samples, and some important factors to be considered in making the tests.

The most generally accepted test method has been the double knife-edge method, in which a glass rod sample 6 in. long and ¼ in. in diameter is supported on knife edges 4 in. apart. The load is applied by means of a centrally located double knife-edge with the edges spaced 2 in. apart. Loading has been accomplished in various ways, the object being to maintain a constant rate of loading. It is known that the actual rate of loading is a very important factor. The breaking stress is calculated from the formula:

$$S = \frac{4\,W\,a}{\pi\,r^3}$$

in which W = weight applied, a = distance between one upper knife edge to nearest lower knife edge, and r = radius of the glass rod.

Samples of three glasses in the form of ¼ in. cane were distributed by Corning Glass Works to the cooperating laboratories. These were tested as received and were also tested after various kinds of abuse to simulate the effect of prolonged use. These treatments have included hand polishing, re-annealing, abrasion with emery cloth, boiling in water and caustic solutions, longitudinal and peripheral scratches, sandblasting, drawing through a box of carborundum, and rotation between steel laps with emery and water. The committee finally considered two methods of preparing the test



● *Parallel faces made by:—1. rough grinding with No. 220 Carborundum and 2. fine grinding with No. 302 Emery*

OLD FRIENDS, NEW FACES AT THE SUMMER MEETING OF THE GLASS DIVISION.

Ray W. Wampler of Libbey-Owens is taken on a personally conducted tour of the Penn State Laboratories.

Francis Flint, James Bailey, Rolf Schultze, and Donald Sharp. These four gentlemen sailed the Rhine together last summer. Dr. Schultze is Technical Editor of Glastech. Ber.

Samuel R. Scholes and R. R. Shively. "Sam" and "Doc" have been friends since 1911, when they were in Mellon Institute together.

W. R. Lester, with Doctors Flint and Sullivan in front of the Nittany Lion.

Inspecting a very unusual collection of silicates in the Mineral Industries Building. J. S. Gregorius, W. M. Clark, C. D. Spencer, V. C. Swicker and G. E. F. Lundell.

This lone glassman, need we say, is Murray R. Scott, of Bausch & Lomb.

Penn State does the honors to the University of Illinois. Dr. Nelson W. Taylor escorts Professor Parmelee through his ceramic laboratories.

Charles McMullen and R. C. Benner, Carborundum Co., are discussing the new "Monofrax" refractories.

R. A. Miller of Pittsburgh Plate pauses a moment on the steps of the Mineral Industries building at the request of the cameraman.

The "big three" of the Glass Division. R. B. Sosman, president of the American Ceramic Society, and Secretary Purdy. Right is A. N. Finn, chairman of the Division.

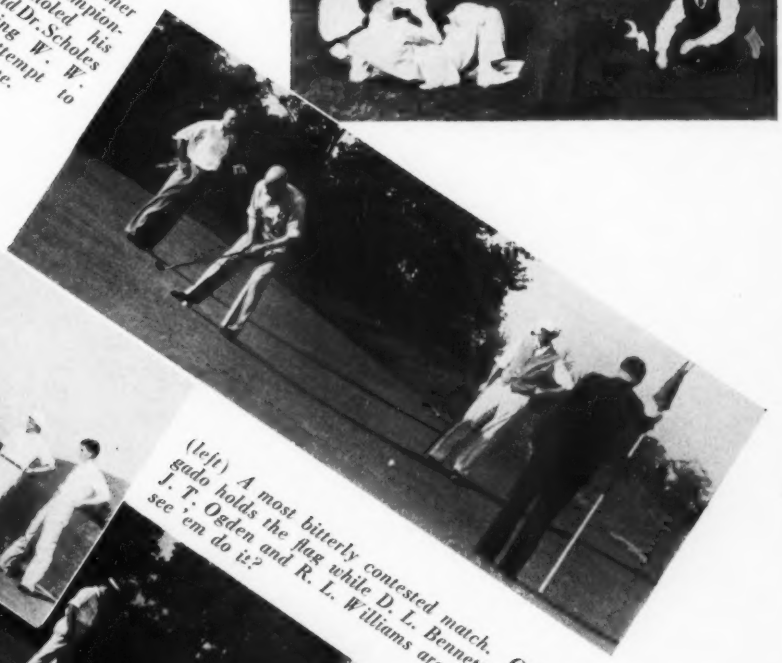
E. L. Hettinger, Ross Purdy and F. E. Bardro

Candid camera shots of the follow through, as posed for the photographer by O. S. Filcher, J. T. Littleton, V. V. Kelsey and H. C. Bates, respectively.

Waiting for the first foursome to come home. Non-golfing fans rest for a moment on the fairways of the Center Hills Country Club.

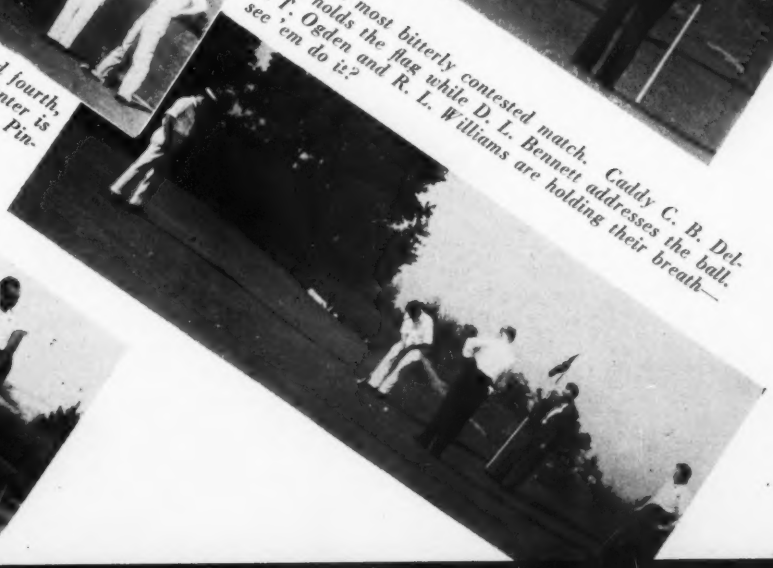
J. T. Littleton, runner up for the championship, has holed his putt. He and Dr. Scholes are watching W. W. Willson's attempt to sink a long one.

Two winners in this foursome. C. C. Treischel, who finished fourth, is putting. The gentleman with the hat is H. C. Bates. Center is G. E. Fulcher, and extreme right the champion V. V. Kelsey. Pinboy, G. C. Strubler.



(left) A most bitterly contested match. Caddy C. B. Delgado holds the flag while D. L. Bennett addresses the ball. J. T. Ogden and R. L. Williams are holding their breath—see 'em do it?

A. L. Houze, Jr., just misses the rough. Watching him is V. H. Remington.



piece, (a) the Hartford-Empire tumbling method and (b) the Corning "velvet-finish" method.

The objective in the selection of a standard preparation method is to secure a small percentage variation in results and at the same time offer a treatment that can be practically and easily duplicated in all the laboratories. Although neither of these methods offers great advantages over the other, on the basis of results so far obtained, the committee has selected the "velvet-finish" method for further test procedure. The dimensions and treatment of the "velvet-finish" specimen are shown below.

Any attempt to analyze the figures from tests made so far is very confusing, since the values vary up to 100 per cent or more on the same sample, and the various preparation methods seem to affect the sample in very surprising ways. It has been shown, however, that boiling increases the tensile strength, so this treatment can be eliminated.

In conclusion Dr. Navias suggested that most samples are abraded in ordinary handling and that a big question is the size of the safety factor. The objective of standard test methods has not yet been reached, but some sign-boards for further procedure have been erected. He hoped that he had "given a real confused idea of the problem of tensile strength determination."

Discussion—Chairman Finn thought that Dr. Navias had given "a masterly review of a messy situation."

Howard described tests made at the Butler, Pa., laboratory, using rectangular specimens of plate glass in which all of the strength values were within plus or minus 10 per cent.

Dr. Littleton discussed the reasons for the selection of rod for test pieces and stated that the ultimate plan is to investigate cross-sections of various shapes. He suggested that the edge polish of the rectangular sections is very important and thought that the "velvet-finish" specimen has an advantage in having no sharp corners.

Dr. Navias presented further plans for cooperative endeavor between the American Ceramic Society, the American Society for Testing Materials and the International Congress on Glass. The American Ceramic Society applied to A. S. T. M. for the formation of Committee C14, since this committee would then have international standing with the foreign investigators. There will be six sub-committees, and Sub-Committee 4 will continue work on the mechanical strength of glass. Internationally the work will be divided, the American workers taking the mechanical strength, with the English and German laboratories undertaking the thermal and chemical investigations, respectively.

Dr. Schulze outlined the use of tensile pull test, stating that it was much used in Germany and should give a smaller spread in results, an economic factor of importance in the determination of a usable "security" factor. He thought the tensile test not so much affected by "bad spots."

Dr. Littleton gave as reasons for the use of bending tests the fact that the knife-edge method throws the area under uniform stress and that both tensile and bending tests are affected by "bad spots." The treatment of the sample is for the purpose of securing weak spots that might occur in normal use. Applicable results are the objective and not high strength values, which are of doubtful value. Tensile tests are more difficult to perform accurately than the transverse.

Chairman Finn stated that tensile tests had been tried at the Bureau of Standards, but the difficulties of the test were too great and the straightness of the specimen was found to be an important factor. Results were not too good.

Sherwood inquired whether the test methods and the modulus obtained were supposed to be used by engineers or simply to indicate the proper type of glass.

Navias replied that these tests had been requested as a working basis to compare glass with other materials. Engineers are interested in properties and there were no methods or values applicable to glass. The object is to determine methods similar to standard test methods developed by the A. S. T. M. for other materials.

Summary of the Results of X-Ray Studies of Glass, by B. E. Warren, Dept. of Physics, Massachusetts Institute of Technology.

To secure the X-ray diffraction pattern of glass a narrow pencil of properly filtered radiation is obtained by passing through two pin holes or through a fine tube. The collimated beam falls upon the glass sample, which may be a thin slip or a small cylinder. The diffracted radiation is allowed to fall upon a photographic film. For quantitative work, and especially for the Fourier analysis, the X-ray beam is made more nearly monochromatic by reflecting from a crystal such as rock salt, and air scattering is eliminated by evacuating the camera.

The two extreme types of diffraction pattern are the liquid pattern and the crystalline powder pattern. The pattern of a liquid consists of one or more very broad, diffuse rings, the pattern of a good crystalline material having a number of quite sharp rings. For all true glasses the X-ray pattern is of the broad ring or liquid type, and this has come to be called the amorphous type of pattern.

Most of the early investigators made no serious attempt to interpret their patterns, but a few workers, including Randall, Rooksby and Cooper, observed a certain similarity between glass patterns and those of the corresponding crystalline material. This was the basis of their crystallite theory of glass, which assumed that glass could be considered as an aggregation of extremely small crystals.

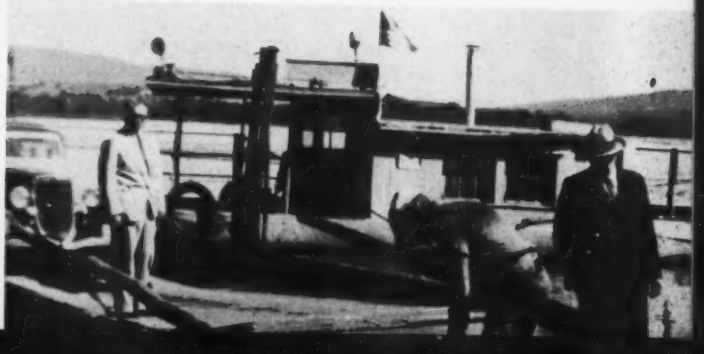
The first attempt to give a detailed picture of the atomic arrangement in a silicate glass, which would be in line with present-day structural theories, was reported by Zachariasen in 1932 (*Jour. Amer. Chem. Soc.*). He pictured vitreous silica as a random network in which each silicon is tetrahedrally surrounded by four oxygens at a distance of about 1.60°A, with each oxygen bonded between two silicons and the angle between two bonds to an oxygen varying considerably. Under these conditions it is possible to build up an extended network without any unit of structure necessarily repeating itself at regular intervals, and the material would therefore be non-crystalline even though the same coordination numbers and interatomic distances exist as in the crystal.

Zachariasen emphasized the importance of each oxygen being bonded to only two silicons and also pointed out that in binary glasses, such as soda-silica, one should expect a silicon-oxygen framework with each

Photos by Hettinger, Strubler and G. I. staff photographers

More views of the Glass Division meeting. Most of these were taken at the banquet and entertainment given at the Center Hills Country Club by Pennsylvania Glass Sand Co. The most important conclusion to be drawn is that glassmen enjoy their "chow" fully as much as the general run of men.

Note particularly two pictures down toward the bottom of the page. The group about the piano are neither glassmen nor their sweethearts b' Penn State students who did the entertaining while the eaters ate. There was more to this picture, but the bottom was cropped off by an artist who lacked a true sense of human-interest values. The little square cut was already adequately captioned before we took the picture.



This final view shows the extreme measures a glassman will take to get to a Glass Division meeting. Messrs. Sosman and Bailey were snapped on their journey to Penn State.

silicon tetrahedrally surrounded by four oxygens, part of the oxygens bonded between two silicons and part to only one. The sodium atom would be distributed at random in the soles in the silicon-oxygen framework.

In a paper in the *Jour. Chem. Phys.*, 1935, Gunnar Hägg has criticized Zachariasen's theory and points out that glass-forming ability depends upon the existence in the melt of large and irregular groupings which produce a high viscosity and allow marked super-cooling of the melt. The atoms are too tightly held in the tangled groupings of the viscous melt to pull themselves apart and rearrange for crystallization. However, Hägg apparently has not realized that, although his requirements are perfectly general and correct, they are not sufficiently specific to apply in the prediction of glass-forming properties in oxide melts, whereas Zachariasen's rules can be applied exactly.

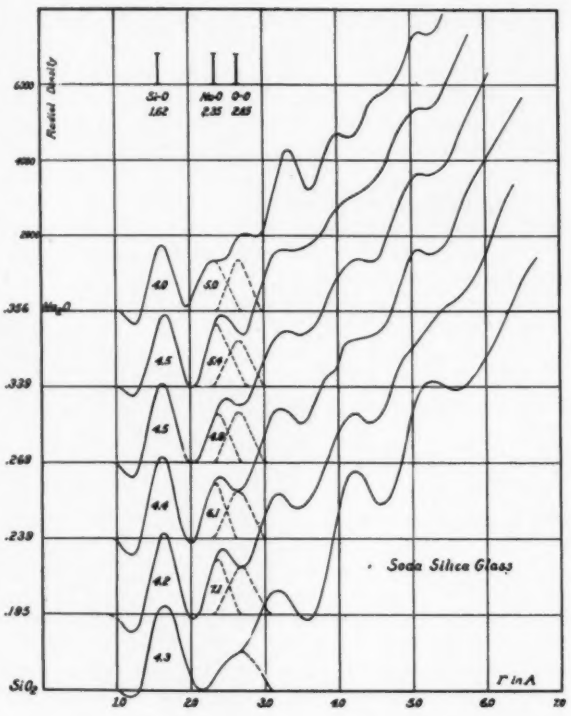
The existence of a viscous melt demands that the atoms or molecules can bond together in a variety of ways, so that there is a pronounced flexibility in the scheme of joining. Zachariasen's rules for the oxide glasses are also exactly the conditions for a viscous melt, and he has quite correctly emphasized the importance of the anions being bonded to not more than two of the principal cations (Si and B). It is just this feature which introduces the necessary flexibility for the existence of a viscous melt.

From the Fourier analysis of the X-ray pattern of vitreous silica it is found that each silicon is surrounded by four oxygens at a distance of 1.60A. That the four oxygens are tetrahedrally arranged about the silicon is suggested by the fact that this is so in all crystalline silicates, and is established by the oxygen-oxygen distance obtained from the Fourier analysis. It then follows that each oxygen is bonded between two silicons. The existence of an indefinite network in vitreous silica in which each silica is in tetrahedral coordination and each oxygen shared between two silicons appears to be a unique result of the Fourier analysis.

It has previously been pointed out that the average particles in vitreous silica are too small to be called crystals and that the absence of small scattering indicated a liquid-like continuity in the structure. All of these facts conform so closely to the random network picture that it is difficult to see how any other picture can be brought into agreement with the experimental facts. It seems very likely that, as molten silica cools and stiffens up here and there at a few spots where conditions are favorable, crystals of crystobalite may develop to sufficient size to correctly call them crystals, but the X-ray results prove uniquely that any such crystalline material cannot be more than a small fraction of the whole.

The Fourier analysis of five compositions of soda-silica glass has now been completed. This work has been done by Mr. J. Biscoe and has been made possible by the Glass Fellowship at M. I. T., sponsored by a number of glass manufacturers. The intensity curves show a perfectly continuous transition from SiO_2 to 0.356 Na_2 0.644 SiO_2, the highest soda content studied.

The resulting distribution curves shown in the accompanying cut show that each silicon is again surrounded by four oxygens and again there is no such thing as an SiO_2 molecule in the glass. Subtracting



off the known oxygen-oxygen peak leaves a peak at about 2.35Å. Since 2.35Å is almost exactly the sum of the sodium and oxygen radii, this peak is identified as the sodium-oxygen separation. From the area under this peak it is found that the number of oxygens about a sodium lies somewhere between 5 and 7, as would be expected. Above 3.0Å the curve is too complicated for analysis.

The work on X-ray analysis will be continued on probably one or two more binary series of glasses.

Discussion—The question of the application of the analysis to ternary systems was brought up by Gregorius. Dr. Warren replied that the curve would be very complicated and that the analysis will probably be limited to binary systems.

Dr. Schultze referred to the work recently done by two Russian experimenters that seemed to show the presence of crystallinity in glass and asked the opinion of the speakers regarding the correctness of their results Dr. Warren pointed out the shortcomings of these experiments, including the use of a small camera, no attempt to secure monochromatic radiation, and no evacuation of the camera to reduce extraneous scattering. These workers reported a crystal size of 10 to 15Å, which would be about equal to the size of two unit cells and might possibly be termed "crystal." However, they attempted to show complete continuity between the crystal form and glass, using dry silica gel which is not a glass. The claims cannot be accepted in the light of more accurate analyses.

Chairman Finn inquired about the effect of a small amount of crystals in the glass and also the purity of the constituents. The speaker indicated that a small amount of impurity makes no difference and that the glass might possibly have up to 2 per cent crystals without affecting the result.

HOW TO CUT COMPRESSED AIR COSTS

The cost of compressed air is a recognizable item in the operating budget of any glass plant, and the compressor operator can afford to consider the factors that prevent his compressor plant from functioning at its full efficiency. Economical operation of a compressor system depends in part upon good housekeeping. Dirty or hot intake air, carbon accumulations in the valves, cylinders or lines, dirty water jackets and intercooler tubes, improper lubricants and leaky lines are particularly important, since they not only reduce efficiency but also cause costly shutdowns for repairs.

The cleanliness of the intake air is extremely important. Tests have shown that the air in most industrial centers is heavily laden with abrasive dusts. Around a glass plant, especially in the vicinity of the batch storage and mixing departments, the atmosphere often contains large quantities of soot, batch materials, glass particles and other abrasive dusts. While the amount of such material may appear small on visual observation, yet the volume of air passing through the compressor system is so large that it will quickly deposit an appreciable amount of grit and dirt on valves, valve passages and in the cylinder. When deposited in the cylinder the grit and dirt become mixed with the cylinder lubricant to form an abrasive paste, and this causes both the valves and the pistons to wear rapidly. The mixture of oil and dirt can also form a deposit that will interfere with the proper movement and seating of the valves. Sometimes the mixture of oil and dirt accumulates in the valve passages to such an extent that the flow of air is seriously impeded.

The use of filtered intake air is strongly recommended. There are a number of air filters on the market that are suitable for use in compressor systems. Some filters incorporate a deflecting device that throws aside the dirt particles; others retain the debris on an oil-coated surface. A useful filter can be made by building around the intake a framework in which are placed a number of removable sashes covered with cheesecloth. At least 1 sq. ft. of cheesecloth surface for every 25 cu. ft. of free air per minute of capacity must be allowed. Regardless of the type of filter used, it is essential that it be cleaned periodically—a dirty filter seriously obstructs the passage of air.

Economical operation of the compressor also depends upon the temperature of the intake air. The use of warm intake air in the compressor reduces the output of the compressor for the same horse-power consumption. To compress a square foot of air from atmospheric pressure to 40 lb. per sq. in., for example, requires a definite amount of power. At a temperature of 70° F. the unit volume of air has a certain definite weight, but at a higher temperature the weight of the unit volume of air will be less. Therefore, the power required to compress a given volume of air to a given pressure varies with the temperature of the air.

The effect of the intake air temperature on the final delivery is given in Table 1, from which it can be seen that drawing intake air from some cool outside source produces a considerable power saving. The cooler the location the more economical the operation, since every 5° drop in intake temperature effects a power saving of nearly one per cent.

Table 1. Effect of Intake Temperature on Power Required to Compress 1,000 cu. ft. Free Air. Delivery Temp. 70° F.)

Temp. of Intake deg. F	Relative Intake Volume Required in cu. ft.	Per cent H. P. Saving
30	925	7.5
40	943	5.7
50	962	3.8
60	981	1.9
70	1000	0.0
80	1019	1.9
90	1038	3.8
100	1057	5.7
110	1076	7.6
120	1095	9.6

The use of hard water for cooling the compressor and intercooler affects the efficiency, due to the formation of scale on the cooling surfaces. The deposition of mud and rust in the water jacket and intercooler also decreases the flow of water and prevents satisfactory cooling. Periodic cleaning of water jackets and intercoolers is necessary to keep them free of mud, rust and scale. Small deposits of mud and loose scale can be removed from the water jacket by a strong jet of water. When a hard, thick scale is present, chemical cleaning is often necessary.

Regardless of the type of oil used, some carbon and oil will always be deposited in the compressor system and must be periodically removed. Kerosene and gasoline are very effective cleansing agents but they should not be used when the compressor is operating because of the danger of a serious explosion. Oil and carbon deposits can also be removed from the compressor and valves by a mixture of soft soap and water, a good cleansing solution being made from 1 part soft soap to 15 parts of water. This mixture is fed into the compressor lubricator in place of the oil on the average of about one day a week. Running the compressor with this mixture will effectively clean the oily and carbonized deposits from the places where the mixture reaches. This soap solution is not a good lubricant and the feed must be about ten times as rapid as the usual oil-feed rate.

Excessive carbonization of the lubrication oil may be due to any of the following causes: 1. The use of the improper type of oil; i.e., one that has low flash and fire points and which decomposes at the temperature encountered in the compressor. (Table 2 gives the theoretical temperature in the cylinder for various air pressures.) 2. The use of heavy oils that do not readily atomize but remain on the hot cylinder walls until they bake into a gummy carbon deposit. 3. The use of too much oil (regardless of quality) for lubrication, leaving an excess which bakes down to a hard deposit. When selecting an oil, particular attention must be paid to its flash and fire points, its tendency to carbonize and its viscosity.

Finally, the air lines, valves and joints should be

Table 2. Theoretical Cylinder Temperature at End of Piston Stroke Based on Adiabatic Compression.

Delivery Pressure (lbs.)	Final Temperature Single-stage. (°F)	Final Temperature Double-stage. (°F)
20	207	—
40	302	—
60	375	203
80	432	224
100	485	243
120	529	257
140	570	272

inspected for leakage at regular intervals. A small leak may appear to be an insignificant loss, but it becomes appreciable if allowed to continue. To detect leakage a lighted candle may be held next to all joints and valves, or soapy water may be swabbed around the joints. An exceptionally good method is the use of a harmless but strong-smelling volatile chemical such as essence of perpermint or amyl alcohol. The chemical may be introduced at the intake and the slightest leak can be located by the odor of the escaping air.

SLAGGING OF GLASS TANK REFRACTORIES ABOVE THE METAL LINE

Due to an error in translating Dr. Jebsen-Marwedel's article under the above title in the September issue of THE GLASS INDUSTRY, the first paragraph of column two, page 306, is not clear and should read as follows:

"Two cases may now be brought into view. In the first case, the glaze on the inner (face) of the furnace is enriched with siliceous acid toward silica to the points ○○○○○. Following gravity, it flows farther down upon the underlying sillimanite. The composition of the reaction mixture moves in this instant toward the sillimanite point corresponding to the – – – – – reaction path in the diagram. The eutectic given by Rice at 5.33 per cent Al_2O_3, 17.55 per cent Na_2O, and 77.12 per cent SiO_2 (800°) can therefore be avoided by a slight increase in the SiO_2 content. The other way about, if the glaze first takes up solution constituents from the sillimanite to the points ● ● ● ● ● and then has its first opportunity to attack silica, then the raction follows the — · — · — · path."

The translator's chief error was in rendering both "gestrichelten Reaktionsweg" and "strichpunktierte Weg" as "shaded area."

FORD TO MEASURE GLASS TO MILLIONTH-INCH PRECISION

The Ford Motor Company has announced the development of a new instrument, the profilometer, by which it is possible to measure instantly variations of a millionth of an inch in the surface of a sheet of glass while in the process of manufacture.

The device consists of a metal box, which is attached to an amplifying cabinet by a five-wire electric cable. On top of the box is a dial; in the bottom, a diamond tipped needle. As the box is pushed across the surface to be measured, the needle follows the contours. Variations in the surface cause variations in the electric current. These are amplified in the cabinet and returned to the dial, which gives an instantaneous reading. By watching the flickering of the needle closely, the operator can tell immediately the location and depth of any roughness.

The profilometer is made use of during the grinding and polishing operations. Any unusual roughness in the surface indicates the possibility of an inaccurate mix, or of an improper grade of sand in the grinders. By means of the profilometer, unusual roughnesses can be detected and remedies applied long before maximum tolerances are reached.

The result, naturally, is a reduction in waste and a higher degree of uniformity in the finished product. The Ford Motor Company comments "The profilometer enables us to take still another step on the long road that has been travelled in recent years in transforming glass making from a hit or miss, rule of thumb business to an exact science."

DUTIES MAY BE LOWERED ON IMPORTATIONS OF GLASS

Glassmen have been greatly alarmed over the products which the State Department has announced it will consider in negotiating a reciprocal trade treaty with Czechoslovakia. The list includes practically all types of glassware. Under the most favored nation policy Japan, a direct competitor of Czechoslovakia, will enjoy to an equal extent any concessions which the United States makes to the latter country. In other words, if this country lowers the duty on importations of glassware from Czechoslovakia, it must lower them correspondingly on Japanese imports—and the havoc which the latter country's merchandise has already brought is known only too well. Trade associations have presented vigorous protests.

GLASS BEING SPRAYED ON COLD METAL

The issuance of patent 1,085,278 on a machine for spraying powdered glass or porcelain enamel, brings to attention a most interesting development in the application of glass as a modern coating material. The Strubler process, as it is called, consists of a machine with an elongated heating chamber through which powdered glass is forced by gas burners; and the use of a long chamber, which allows the glass particles to become heated throughout their mass. The small particles of glass are projected through the heated chamber at the speed approaching that of a bullet, and upon impact with the surface to be coated, they form a coating much like sleet. The glass adherence is said to be far better by this method than when it is fired on by the conventional method, having no bubbles at the metal line. Pieces of test plate have been bent to an arc of 5/16″ per ft. without damage to the glass coating.

The inventor, Gordon E. Strobler, states that in his opinion one of the principal uses will be to coat ship bottoms with glass instead of with paint, as a permanent protection to the metal. This would eliminate yearly drydocking or barnacle scraping, because from all available information barnacles will not adhere to a glass surface. Of other proposed uses, outdoor steel structures, bridges, steel houses, steel tanks, too large for firing ovens, are but a few. This would make it possible to apply a glass coating to structures already erected, made of iron, steel or ceramic materials.

Personalities in the News

F. E. BARDROF JOINS OUR STAFF

THE GLASS INDUSTRY is pleased to announce the appointment of Frank E. Bardrof to the position of Associate Editor. Mr. Bardrof is an engineer, a glassman, and an editor. Graduated from Rensselaer Polytechnic Institute with an M.E. degree, he taught mechanical engineering there for several years. At the Corning Glass Works, he was for six years engaged in the design, development and manufacture of glassmaking machinery. His special talent for all things mechanical attracted the attention of the *American Machinist*, of which he then became Associate Editor. More recently he did an outstanding job as sales manager of the Cleveland Worm and Gear Company. Mr. Bardrof's unusually fine background of experience will supplement the staff of THE GLASS INDUSTRY, and enable the publication to serve its readers with even greater efficiency in the future.

• Dr. Ralph K. Day has severed his connection with the Corning Glass Works to become associated with the laboratory of the Spencer Lens Co., Buffalo, N. Y.

• Harold Snyder has accepted a position with Hocking Glass Co., Lancaster, Ohio. Mr. Snyder was formerly in the mechanical development department of the Corning Glass Works.

• George S. Cooper is the newly elected vice-president in charge of sales of the Diamond Alkali Co., Pittsburgh.

• Banks D. Brown, superintendent at the South Connellsville, Pa., plant of Capstan Glass Co., has been promoted to factories superintendent in supervisory charge of Capstan plants at both South Connellsville and Salem, N. J. Succeeding Mr. Brown is his former assistant, J. C. Schwab who becomes superintendent at South Connellsville. A graduate of Carnegie Tech., Mr. Schwab has been with the U. S. Glass Co., Pittsburgh, General Electric Co., at Niles, Ohio, and Hazel-Atlas at Wheeling.

A. E. BADGER IN GERMANY

A. E. Badger, Research Associate of the University of Illinois Engineering Experiment Station, who is connected with the Department of Ceramic Engineering, sailed on September 12, for Germany where he will go to the Kaiser-Wilhelm-Institut für Silikatforschung at Berlin—Dahlem.

John D. Biggers

Amory Houghton

Edward F. Pink

George S. Cooper

Mr. Badger will be there on leave of absence from the University for a period of several months in order to engage in research work under Dr. Woldemar Weyl. The particular project in which he is interested is the coloration of glass by the use of vanadium and some other oxides.

DEATH OF EDWARD F. PINK

It is with deep regret that THE GLASS INDUSTRY records the death of Edward F. Pink, president of the Cambridge Wire Cloth Co., Cambridge, Md. Born in 1868 in Brooklyn, N. Y., Mr. Pink at the age of 12 began his apprenticeship as a wire cloth weaver. When the Estey Wire Works moved their plant to Cambridge, he went with them as plant foreman. In 1915, he formed the Cambridge Wire Cloth Co. and leased the plant and equipment of the Estey Co. In 1920, the Cambridge Wire Cloth Co. was reorganized with Mr. Pink remaining as president, his brother Robert W. Pink becoming vice-president and his son, Clarence Pink, secretary and treasurer. In addition to an active business career, Mr. Pink was active in fraternal and church work.

BIGGERS TO DIRECT CENSUS OF IDLE

• After a conference at the White House on Sept. 16, John D. Biggers, president of the Libbey-Owens-Ford Glass Co., accepted an invitation from President Roosevelt to be administrator of the census of the unemployed. Mr. Biggers set up an office in the Commerce Department and went right to work. Because he believed that economy should start at the top, Mr. Biggers told the President he didn't want any salary, but F. D. R. insisted on $10,000 a year. Mr. Biggers still has hopes of working for nothing. He commented, "I hope the President will humor me. I am accepting this job because I believe that such a job will be of great value and that I can perform a useful public service."

• Most recently elected director of the National City Bank of New York is Amory Houghton, president of Corning Glass Works. This makes No. 9 on Mr. Houghton's list of directorships.

SILVERMAN ADDRESSES CHEMISTS

Dr. Alexander Silverman, Head of the Department of Chemistry, University of Pittsburgh, gave an illustrated talk to the members of the Division of the History of Chemistry at the American Chemical Society convention, Sept. 6, on the life of Henry Le Chatelier.

SOME APPLICATIONS OF NICKEL ALLOYS IN THE GLASS INDUSTRY

• *Very little has appeared in the American literature on the subject of the applications of nickel in the glass industry. Therefore, for the sources of material in the present article, it has been necessary to draw upon English writing, upon the files of the International Nickel Company, and upon the experience of glassmen themselves. No mention at all is made of molds, which will be discussed separately in a later article. The treatment of the subject in the present paper is necessarily general, but* THE GLASS INDUSTRY *welcomes any inquiries on specific problems and will gladly help toward their solution.—The Editor.*

The manufacture of glass, primarily a high-temperature process, is another industry in which the metallurgist has been called upon to provide materials of construction capable of long and reliable service under generally destructive conditions. To a large extent he has met this demand by the development and improvement of heat-resisting alloys of nickel, one or other of which is today giving excellent service in certain vital parts of glass-making equipment.

The heat-resisting nickel alloys available for such service may be divided, broadly, into the following groups:

1. Cast irons containing up to three per cent of nickel, with or without chromium. Their heat-resisting properties are superior to those of ordinary cast iron, but they cannot be compared with those of the true heat-resisting alloys.

2. High-alloy cast irons such as "Ni-Resist" and "Nicrosilal," containing up to 20 per cent nickel. These alloys are austenitic in structure and have a high resistance to oxidation and growth, but are not generally suitable for temperatures above 800°C (1472°F). Even at this temperature their strength is low.

3. Wrought and cast heat-resisting austenitic steels containing up to 36 per cent of nickel and 30 per cent chromium, with or without additions of silicon, tungsten, etc. This group can be used, under suitable conditions, at temperatures up to 1050°C (1922°F) and is regularly employed for a wide range of high-temperature work.

4. The nickel-chromium and nickel-chromium-iron alloys containing high percentages of nickel, with or without other alloy additions. This group probably offers the best combination of properties at high temperatures.

The choice of the most suitable alloy for any particular piece of glass-making equipment depends, of course, upon local requirements. Cost, creep strength, oxidation-resistance, form required, heat conductivity, etc., must all be taken into consideration. Special precautions are needed when sulphurous atmospheres are to be encountered and special modifications of the above alloys have been developed to meet such conditions.

A few examples of the successful use of these various heat-resisting alloys in typical glass-making equipment will probably serve to illustrate their potentialities better than a review of their properties under test conditions.

Melting Equipment

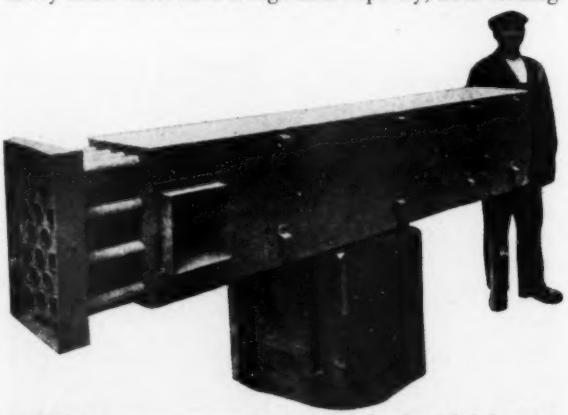
Melting furnaces, whether of the pot or tank type, operate at such high temperatures (1300°-1400°C) or (2372°-2552°F), that unless air- or water-cooling is adopted no metals can be used for parts which are in contact with the glass for any length of time.

In water cooled tank outlets and lips, through which the molten glass is drawn, however, the conditions permit the economical use of a heat-resisting alloy. The molten glass, in its passage, tends to produce an oxide scale which, in a metal such as cast iron, is fluxed away by the glass and thus causes both rapid wear of the lip and contamination of the glass. The substitution of cast iron by a nickel-chromium-iron alloy goes a long way towards the solution of this problem.

In the regenerative type glass-melting furnaces, as in open hearth steel melting furnaces, nickel-chromium-iron alloys are used in the regenerator reversing valves when producer gas is used for firing. The only practicable method of removing carbon deposits from the mushroom type valves is to burn it out, a process which generates intense heat and therefore necessitates the use of such heat-resisting alloys.

The replacement of firebrick by heat-resisting alloys in regenerators has interesting possibilities; for the latter, having a heat capacity per unit volume three times that of firebrick and a tenfold superiority in the diffusion of heat, would permit the use of a much smaller regenerative chamber. On the other hand, the rapid interchange of heat demands rapid reversals which would possibly lead to loss of heat during the frequent change-overs and might also have mechanical complications.

The use of heat-resisting nickel alloys in glass-melting furnaces operated on the recuperative system is widely established. In such an application fireclay has the drawback of fragility so that its use leads to leakage through cracks. It has also a low heat conductivity and the necessarily thick walls have a high heat capacity, both leading



• *Built-up recuperator unit constructed of nickel-chromium heat-resisting alloy.*

to poor efficiency—from the recuperative point of view. A heat-resisting alloy, selected according to the operating temperatures, has none of the defects of fireclay, and has the positive advantage that by permitting higher velocities it enables a better use to be made of the heat-transmitting surfaces.

The nickel alloys employed for this purpose are free from growth and from excessive scaling, and thus one of the risks attending the use of metallic recuperators—loss of efficiency in heat transference due to scale—is avoided. Their workability and their good mechanical properties at high temperatures permit the production and the use of thin sections so that the size of the recuperator can be materially reduced.

It must be remembered, however, that alloys in which the nickel is higher than the chromium content should not be used in high sulphur atmospheres. In the case of alkaline dusts such as are found in glass regenerator or recuperator chambers the various type nickel alloys given in Table I all should withstand the action of such dusts.

Bars and tubes used for pot setting and in preparing furnace benches are exposed to full furnace heat, but as the periods of exposure are short, the maximum temperature reached is not so high as to prohibit the safe use of metals. Economies are obtained by the use of

TABLE I

(A) Composition of Cast Alloys

	Nickel	Chromium	Carbon	Iron
1.	60-65	15-20	.25-.90	Bal.
2.	35-40	15-20	.25-.90	"
3.*	19-21	24-26	.25-.90	"
4.	10-13	26-29	.25-.90	"
5.	8-12	18-20	.25-.90	"

*This alloy sometimes contains 0.7 to 3.0 Silicon.

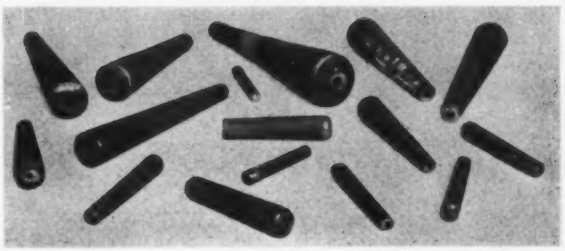
(B) Mechanical Properties

	Alloy	Breaking Strength	Yield Strength	Elongation	Reduction of Area
1.	60-15	70-120,000	50-60,000	25	50
2.	35-15	60-100,000	40-50,000	40	50
3.	20-25	76- 85,000	40-53,000	30	30
4.	12-28	90-105,000	45-62,000	29	27
5.	8-18	80-105,000	55-75,000	10	10

TABLE II

	A	B
Total carbon	3.60	2.80-3.00
Silica	1.00	1.50-2.00
Sulphur	0.08 max.	0.08 max.
Phosphorus	0.20 max.	0.20 max.
Manganese	0.5 to 0.6	0.5 to 0.6
Nickel	1.75 to 2.00	1.5 to 2.00
Chromium	.....	0.3 to 0.5*

*When castings are not chilled. *If* chilled, leave out Cr and increase carbon to 3.1-3.4 per cent.
Note: "A" must be cast against a chill to produce a fine grain.



● *Glass blowing nozzles, one of the early uses of nickel-chromium-iron alloys.*

nickel-chromium-iron alloys for these tools. The same alloys are being extensively employed for gas burner tips and are said to give over twenty times the life of cast iron burners.

Working Equipment

Working Equipment. In the removal of molten glass from the melting furnace, whether by ladle, gathering iron or by pouring, the contact surfaces become heated to the temperature of the glass and must, therefore, be made from a material which will resist scaling and will not cause the glass to stick to it. For this purpose also nickel-chromium-iron alloys have been successfully adopted on a wide scale. They have an additional advantage of being unimpaired by the severe conditions resulting from cooling them by quenching in water, a practice regularly conducted by some producers. These alloys are homogeneous and stable at all temperatures so that quenching produces neither the hardening nor the brittleness, warping and cracking so soon encountered in ordinary steels.

As an example, an alloy very similar in composition to the alloy listed as No. 4 in Table I has been used with considerable success for ladles. It has been reported that its resistance to inter-crystalline fracture is such that its life is two and one-half times that of some of the ordinary heat resisting metals.

One of the earliest uses of nickel-chromium-iron alloys in glass-making equipment was for the ends of glass-blowing nozzles or punties. Before this application became generally established practice, however, a number of difficulties had to be overcome. The most serious of these was the problem of avoiding excessive oxidation of the steel during the process of joining the casting to the steel blow tube, but experience in oxy-acetylene welding has now provided an entire solution. The nozzles vary in weight from two or three ounces to several pounds—according to the weight of glass to be gathered—and some of the larger ones are over 3 inches in diameter. The principal advantage of nickel-chromium-iron alloys for this application are their extremely long life, resistance to bending out of shape, and the fact that they eliminate discolorization in the finished product.

Tube punties are also being made from the high-nickel alloys, the general practice being to use the 60-15 per cent (No. 1, Table I) type in cases where high temperature strength is important, and the 35-15 per cent type when less severe conditions prevail.

In feeding glass to bottle-making machinery, successful use has been made for a long time of wrought and cast heat-resisting nickel-chromium alloy plunger rods.

The top portions of these rods are directly exposed to the action of the flames, but the parts which come in contact with the glass are protected by a refractory coating. Cast iron and some ferrous alloys have been found unsuitable for this purpose because they have insufficient strength at the high temperatures involved (between 1100° and 1250°C), but the high-nickel alloys have given good service.

Neck rings also present a metallurgical problem, but the fact that these high-nickel alloys retain their hardness at the temperature of operation has led to their adoption for this purpose. In some cases, however, where the conditions are not so severe, nickel cast iron has proved entirely successful.

Nickel cast iron is being used rather extensively for parison and blow molds. The nickel content is usually kept below 2 per cent, with 1 per cent being an average figure. The use of nickel in these amounts produces a cast iron that exhibits far less growth than ordinary cast iron in addition to a close grain surface and good machinability. Table II gives the composition of two nickel cast irons suitable for glass molds.

For plate glass bending rolls, high-nickel nickel-chromium-iron castings six to seven inches in diameter and up to 10 feet in length are in general use. They are usually made hollow to facilitate cooling. Operating at a temperature of 700°-800°C, a good roll will need redressing after about thirty days, but the amount of metal removed is so small that the actual life of a good roll is many years. It is not discarded until it is nearly an inch below its original diameter.

From the bending roll, the hot plates are conveyed to the flattening table and annealing lehr over metal rolls. These rolls are of the same length as the bending roll, but have a smaller diameter. They are also made hollow to permit air cooling. As the service is not so drastic as that required from the bending roll, the use of one of the recognized heat-resisting nickel-chromium-iron alloys is not essential and the conditions are adequately met by nickel or Monel. These metals have the advantage that they do not mark the plate in any way. Recent developments have made it possible to obtain the advantages of these metals at a comparatively low cost, by the use of steel rolls covered with nickel or Monel sheet by welding.

It must be pointed out that the actual conditions under which rolls and tables for sheet and plate glass have to operate vary considerably and, therefore, that in some circumstances low- and high-alloy cast irons are giving satisfactory service, while in others nickel-chromium-iron alloys are required.

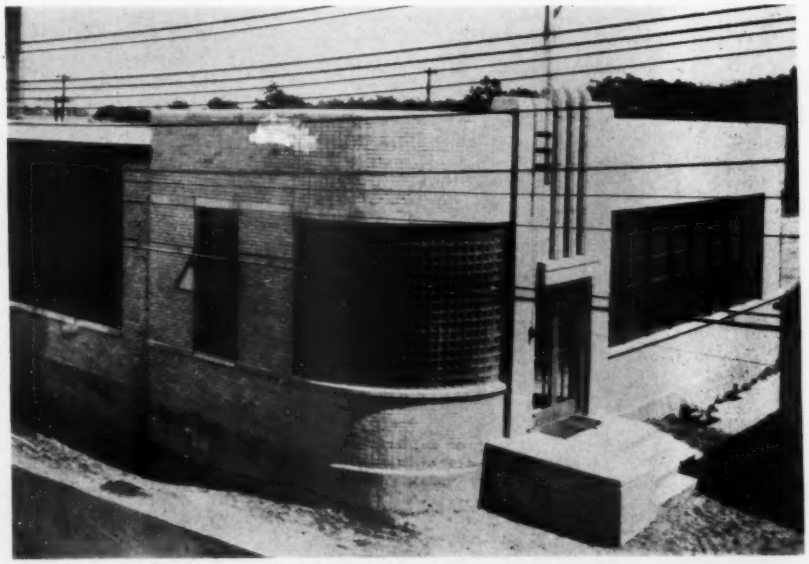
Annealing Equipment

Annealing Equipment. Considerable development in the construction of lehrs has been made possible by the use of heat-resisting nickel alloys. In indirect-fired lehrs, nickel-chromium alloys have given excellent service in the form of muffles, while nickel-chromium box flues are used to insure a regular transfer of heat in both top and bottom of the muffle, thus insuring even soaking of the work.

The rollers, belts, supports, etc., in continuous-belt direct-fired lehrs and the flues in indirect-fired lehrs are subjected to the action of combustion gases which frequently contain sulphur. Special attention must be paid to this point, therefore, when seeking the best material for such a purpose.

Nickel-chromium alloy burners—for gas or oil—have a life of many years, because of a low oxidation rate.

Miscellaneous Uses. Other uses of nickel alloys in the glass making industry include pyrometer tubes, thermocouple wire, electric furnace heating elements, in all of which heat-resistance is of importance. Monel finds employment in cases where strength and corrosion resistance are of first importance, such as hydrofluoric acid glass pickling equipment and acetate handling equipment, used in the production of safety glass.



● *The T. C. Wheaton Company's new creative art department and glass stopper grinding room, said to be the world's most up-to-date, are located in this modern building designed and recently completed by The Austin Co., at Millville, N. J.*

FIBRE BOXES AS A CAUSE OF BLOOM

By G. R. McDANIEL*

• *This investigation by Dr. McDaniel does not pretend to be a thoroughgoing study of durability of container glass. It is reassuring, nevertheless, because it shows that a commercially durable glass could not be induced to "bloom" by the silicate of soda contained in a very large quantity of paper-box dust, under the worst conditions of humidity and condensation. The Editor.*

At various times statements have been made that glass containers, packed and shipped in corrugated boxes bonded with silicate of soda adhesive, sometimes show etching or blooming on the glass surface. The argument maintained is that the small amount of dust in the boxes and corrugated partitions used in boxes for transportation of glassware settles on the glass and causes this efflorescence after a period of time. Quite often it is claimed that particles of dried silicate of soda in this dust are responsible, particularly when glassware is stored in damp warehouses.

Since such statements apparently have not been based upon controlled experimental data, a series of tests were carried out to determine whether or not the silicate of soda used as the adhesive in fabricating the boxes really causes blooming. It is a well known fact that a certain amount of dust and lint results from the cutting and slitting of partitions, and a small portion of this settles on the surfaces and within the corrugations of the partitions. During shipment the dust is shaken loose from the partitions and settles on the ware. The proper handling of partitions during manufacture greatly reduces the amount of dust left in the partitions.

Experimental

A quantity of lint and dust from the partition-cutting operation was obtained from a corrugating box plant, and analyzed for silicate of soda. The amount was found to be approximately 5 per cent dried silicate of soda.

A number of 8 oz. glass jars of the type ordinarily used for mustard were employed for the tests. The jars were numbered, and each jar was treated separately before starting the test, as follows:

No. 1. This jar was taken from a partitioned corrugated box after being shipped from the glass plant to the user. The box was bonded throughout with silicate of soda. The normal amount of dust that had collected in the jar during shipment was not disturbed, and the jar was put through the test in exactly the condition as received by the user.

No. 2. This jar was washed clean, rinsed with distilled water, dried in a hot air oven, and allowed to cool before beginning the test. This jar was the standard against which the others were compared.

No. 3. This jar was washed clean, rinsed with distilled water, dried in a hot air oven, and allowed to cool. Then, the jar was sprinkled inside with dust made from a piece of chip liner such as is used in making the partitions of the boxes for shipment of the glass jars. The dust was obtained by scraping a piece of chip liner with a file; naturally, there was no silicate of soda in this dust.

No. 4. Same as No. 3 except that the jar was sprinkled with dust made from a piece of chestnut corrugating medium, such as is used in making the partitions of the boxes.

No. 5. This jar was washed clean, rinsed with distilled water, dried in a hot air oven, and allowed to cool. Then the jar was sprinkled inside with an abnormal amount of dust and lint, containing silicate of soda adhesive, and obtained from the partition cutting operation in the box plant.

No. 6. Same as No. 1 except that the dust collected during shipment was removed with a dry, clean cloth. The jar was not washed.

The six jars, prepared as above outlined, were then exposed to a saturated atmosphere by placing them without lids over water in a closed glass vessel. The jars were allowed to remain in the closed glass vessel at room temperatures for three days; then removed from vessel, and placed out in the open room for three days. This cycle was repeated until a period of time of five months had elapsed. (*Continued on next page*)

• *Closed glass vessel in which 100 per cent humidity conditions were maintained during test.*

*Research Chemist, Standard Silicate Division, Diamond Alkali Company.

After the humidity tests had been carried out for the five months, none of the mustard jars were found to be etched, or to have bloomed. At times, during the three-day periods at the dew point, small particles of moisture condensed on all of the jars. When these minute particles of water evaporated during the three-day interval in the room, small water specks or spots appeared on the jars. The moisture condensation during the three-day periods at saturation was caused by slight variations in the temperature of the room. This condition is of the same nature as that occurring in a damp storage warehouse in which there are temperature changes. The tests are, therefore, more valuable carried out under the normal temperature changes occurring in the room, which approximate actual storage and shipping conditions, than if the room temperature had been maintained constant throughout the time period of the test. Furthermore, the condensation of minute droplets of water on the jars, thereby actually wetting to some extent the dust particles, was a more severe condition than if a merely saturated atmosphere with no moisture condensation prevailed.

However, the water spots could be easily removed by rubbing with a dry cloth, leaving no trace of bloom or evidence of etching. It is important to note that these spots from moisture condensation occurred on all the bottles including jar No. 2 (a clean, dry jar). It is possible that in the past these small water spots may have been mistaken by the casual observer for blooming, and thus have been responsible for the statements made that boxes bonded with silicate sometimes cause etching of glass containers shipped in them.

The results also show that etching is not caused by dust from the chip liner (jar No. 3), chestnut corrugating medium (jar No. 4), or by the presence of an abnormal amount of dust from the partition cutting operation (jar No. 5).

It may be concluded, therefore, from the results obtained, that glassware of the type used for mustard jars is not etched because of shipment in corrugated partitioned boxes bonded throughout with silicate of soda adhesive.

MONOFRAX REFRACTORIES DEVELOPED AT MELLON INSTITUTE

A new series of super refractories adapted particularly for use in high temperature furnaces and in contact with corrosive materials has been developed recently at Mellon Institute, according to an announcement by Dr. E. R. Weidlein, Director of the Institute. These new refractories, which have been given the trade name "Monofrax," were evolved through the research of Dr. A. P. Thompson, incumbent of the Abrasive Fellowship, in cooperation with the research laboratories of The Carborundum Company.

Several large scale installations of "Monofrax" have already been made in the construction of glass melting furnaces and the performance has been outstandingly successful.

Monofrax blocks are cast, by methods similar to those employed in foundry practice, from a melt produced in the electric furnace. Because of the non-metallic nature of their constituents, however, much higher temperatures are required than in casting iron, and the problems involved are therefore much more complex. Through the use of unique methods of forming the blocks, these obstacles have been largely overcome, with the result that this material is now available commercially.

Monofrax refractories have shown extraordinary resistance to erosive and corrosive attacks at high temperatures, states the Mellon Institute. They have proven to be particularly suitable for those uses in which a refractory is in contact with a high temperature melt, such as glass or slag. One of the preferred compositions, for example, is reported to be six times as resistant to the attack of glass at temperatures of 2700°F. as the best refractory hitherto available.

"GLASS IN ARCHITECTURE"

Of considerable interest and significance in marking the rise of glass to a position of major importance in the architectural and building fields, is the fact that Italy's leading architectural periodical *Rassegna di Architettura* has devoted its latest number (6) in its entirety to "Glass—the New Structural Material."

The issue is remarkable, from both standpoints of appearance and subject matter. Typographically, in format and in the type and character of its illustration, it is comparable to our highly styled class periodicals. Yet the review is essentially a technical book, replete with engineering data of the hand book type which the publishers state has been compiled, revised and edited with special reference to the use of glass.

In its treatment of glass as a structural material, *Rassegna di Architettura No.* 6 deals with many aspects of its subject. Illumination, building contracts, insulating glasses, tempered glass, architecture, the biological action of light—these excerpts from the Table of Contents indicate the scope of its treatment.

American students of construction materials, and particularly glassmen, will find here much of interest.

AUGUST PLATE GLASS PRODUCTION

The Plate Glass Manufacturers of America report total production of Polished Plate Glass by member companies of the Association for the month of August, 1937, to be 17,898,064 sq. ft. This compares with 15,344,855 sq. ft. produced the preceding month, and with 18,710,040 sq. ft. produced in the corresponding month last year, August, 1936.

The Window Glass Manufacturers' Association reports that window glass production was 1,351,948 boxes during August, which represents 83.4 per cent of the industry's capacity. The total production for the first eight months of 1937 was 9,132,010 boxes, representing 70.3 per cent of capacity.

• We have an inquiry for information where a quarter to a half million magnifying glasses 1¼ inches in diameter can be purchased. Address GLASS INDUSTRY.

FOR SALE: One 14 x 14 x 10 Sullivan angle compound air compressor, 910 cu. ft. per minute, 55 lbs. pressure; direct connected to a 120 HP Fairbanks Morse, 2-cylinder, vertical, full Diesel oil engine, complete with a Maxim silencer, circulating pump, oil filter, used only six months, equivalent to new. Fletcher Sales Co., 835 Security Trust Bldg., Indianapolis, Indiana.

EQUIPMENT AND SUPPLIES

MIN-OX ALLOY CASTINGS

Two iron alloys especially developed for high-speed glass machine parts are now being marketed by the Binney Castings Co., 401 Phillips Ave., Toledo, Ohio. These alloys are designated Min-Ox 51-C and Min-Ox JR-3. Min-Ox 51-C is adapted for use under very severe conditions of heat and abrasion. takes a good polish and does not crack or warp. It is said that this material will run more than five times as long as cast iron between cleanings; that it imparts exceptional clearness and brilliancy to the ware, and that it is economical because of time saved in cleaning, changing and repairing. It is used chiefly for pressed mould work and for neck rings on bottle machines. Min-Ox JR-3 has somewhat the same characteristics, but is cheaper in first cost and has a shorter operating life under severe conditions. In order to select the proper alloy it is necessary to know how long the moulds are to be used and what results are required. The company also manufactures a special bronze alloy to be used on large-size neck rings of machines that operate at very high speed. This metal has a high thermal conductivity and is particularly adapted for mould parts that run hot. It resists chemical action and scale formation.

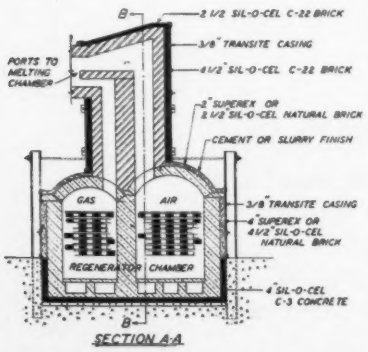
BOOK ON HEAT CONTROL

Johns-Manville, New York, has announced the publication of a handbook entitled "Heat," which covers "the story of man's age-old struggle to control nature's most powerful force." On problems of glass plant insulation, "Heat" comments as follows:

"Whether or not insulation should be used on walls and crowns of glass tanks is a question to be considered specially for each individual job. This matter is now receiving a great deal of attention in the glass industry due in part, perhaps, to the excellent results which have attended the use of insulation on open hearth roofs in the steel industry. There are a number of insulations that will successfully resist the temperatures encountered outside the refractory.

"Sil-O-Cel C-22 Brick on the refining end of continuous tanks also offer an excellent opportunity for fuel savings which should be possible for every plant. In day tanks also, insulation has been used with uniformly beneficial results. A 4½-inch course of Sil-O-Cel C-22 Brick in the walls and a 2½-inch course in the base and over the crown will shorten the melting time, reduce fuel consumption and minimize troubles due to vitrified or cordy glass.

"Insulating the regenerators of glass melting furnaces results in large fuel savings due to reduction in heat losses and the elimination of air infiltration. For example, one plant, by insulating the walls of the regenerators on one furnace with Superex Blocks, was able to reduce the fuel consumption by 26.5 per cent."



● *Johns-Manville recommends the following insulation for glass tank regenerators and uptakes.*

CATALOGS RECEIVED

Technical Information on Wire Cloth and Metallic Screen. Cambridge Wire Cloth Co., Cambridge, Md. Four useful bulletins describing this company's various types of wire cloth and screen under a single cover. Bulletin 75 gives gross list prices and standard weights. Bulletin H-3 describes the use of Monel metal for industrial screen and filter cloth problems. The third describes the company's various products and the fourth deals with the use of stainless steel for this type of equipment.

Glass Batch Mixers. T. L. Smith, 2835 N. 32nd St., Milwaukee. In addition to data on the design and operation of glass batch mixers, this 8-page folder gives complete dimensions and specifications for four different sizes, having glass batch capacities ranging from 28 to 84 cu. feet. Mixers are of the Duo-Cone type and may be equipped with batch-hopper and dust boot, or feed chute and sealing doors. Dust-sealing arrangements are featured.

Bristol's Pyromaster. Bulletin 489, Bristol Co., Waterbury, Conn. A large folder describing the company's new round chart recording potentiometer.

Louis Allis Co., Milwaukee, Wis. A 60-page book which includes valuable data on various types of special motor construction and applications.

Industrial Heating Equipment. Industrial Gas Engineering Co., Inc., 201 East Ohio St., Chicago. A new 32-page catalog listing the company's complete line of high temperature exhausters and air heaters for application to furnaces and ovens. Fully illustrated and with specifications.

Barriers to Industrial Waste. Johns-Manville, 22 East 40th St., New York City. A new edition of a former 68-page booklet of the same name. Amply illustrated, it describes more than 50 different insulations for all types of heated or refrigerated equipment.

IMPROVED VENTILATOR

An improved design of its original rotary ventilator has recently been placed on the market by the Swartwout Co., 18625 Euclid Ave., Cleveland. Improved features are found in the detail construction, foremost of which is the use of stainless-steel, fully-enclosed, dust-tight, oilless ball bearings on which the ventilator turns with the wind. Interior bracing is formed from welded, stream-lined steel tubing, providing maximum strength with small air flow resistance. The improved body design gives a slightly increased area in the discharge opening, thus securing greater capacity per size. The improved rotary is furnished in sizes from 12 to 72 in. throat diameter.

General Refractories Co., Philadelphia, have appointed the Hull Industrial Supply Co. as distributors in the Toledo territory. Hull will carry a complete stock of refractories.

United States Rubber Products, Inc., 1790 Broadway, New York, report that they have designed new blower and dust suction hoses to meet practically every known conveying condition. The dust hose is for abrasives and the blower hose for fumes.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	44.00	48.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)	lb.	....	....
Granulated	In bags, lb.	.021	.0255-.028
Powdered	In bags, lb.	.0235	.028-.0305
Boric acid (H_3BO_3) granulated	In bags, lb.	.0475	.0525-.055
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07⅛
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.08½	.09
Synthetic (Artificial)	lb.	.08½	.09
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	31.50	....
In bags	ton	33.10	38.00-40.60
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.09	....
In 5 Ton lots	lb.	.095	.095
Less than 5 Tons	lb.	.10	.10
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	....
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	....
Burnt, ground, in 280 lb. bbls.	Per bbl.	2.25	2.25
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065-.0675	.07⅜
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	18.00	27.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls.	Per 100 lb.	....	2.25-2.65
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	....	.03½
Aluminum oxide (Al_2O_3)	lb.	.04	.05
Antimony oxide (Sb_2O_3)	lb.	.15	.15½
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03¾
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¼
Rutile (TiO_2) powdered, 95%	lb.	.11-.12	.13-.15
Sodium fluosilicate (Na_2SiF_6)	lb.	.06¼	.06½
Tin Oxide (SnO_2) in bbls.	lb.	....	.60
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls.	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .005-.02c higher)		.07	.07½-.08
Commercial, Gran. (Milled .005-.02c higher)		.03	.04-.05

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.50-1.75
(Commercial, 25% Selenium)	lb.	....	.90
Cadmium sulphide (CdS)	lb.	....	1.50-155
Chromite	lb.	....	.022
Cerium hydrate			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls.	lb.	....	.22-.26
Cobalt oxide (Co_2O_3)			
In bbls	lb.	....	1.67
In 10 lb. tins	lb.	....	1.77
Copper oxide			
Red (Cu_2O)	lb.	....	.20¼
Black (CuO)	lb.	....	.18-20
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425
Black (Fe_3O_4)	lb.	.04½	....
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$)	lb.	....	.16
Manganese, Black Oxide			
In Paper bags	ton	62.50	64.50-66.50
In Burlap bags	ton	65.50	67.50-69.50
In Casks	ton	70.50	72.50-74.50
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.40
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	....	.09
Powdered	lb.	....	.09½
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.20⅜
Rare earth hydrate			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	2.00
In lesser quantities	lb.	....	2.10
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06⅝	.07
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	....	.08⅜
Sodium selenite (Na_2SeO_3)	lb.	....	1.80-2.00
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.50-1.55
Yellow	lb.	....	1.50-1.55
Sodium uranyl carbonate	lb.	....	.80-.90
Sulphur (S)—			
Flowers, in bbls.	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls.	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.25
Yellow orange	lb.	....	1.50

Polishing Materials

		Carlots	Less Carlo
Emery, Turkish	lb.	....	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1.	lb.	....	.03¾
Putty Powder	lb	....	.38-.42
Rotten Stone	lb.	....	.03
Rouge, Red	lb.	....	.14
Black	lb.	....	.16